Mixing Analysis for the Port of Corpus Christi Authority of Nueces County
TPDES Permit No. WQ0005253000

Reviewed by Katie Cunningham
August 10, 2021

This diffuser report supersedes the report by Katie Cunningham, dated July 1, 2020. The TCEQ Commission remanded this permit application to the State Office of Administrative Hearings (SOAH) to take additional evidence. In addition to other information, the applicant submitted a revised diffuser design and relocated proposed Outfall 001 71 feet closer to the shoreline. The purpose of this report is to review the new diffuser design and related information.

Introduction

The Port of Corpus Christi Authority of Nueces County is proposing to construct a marine seawater desalination facility on Harbor Island near Port Aransas. Discharge from Outfall 001 will be via diffuser directly into the Corpus Christi Ship Channel (part of Corpus Christi Bay, Segment No. 2481). The proposed daily average permitted flowrate is 95.6 million gallons per day (MGD) of water treatment wastes from the reverse osmosis (RO) treatment process. The proposed diffuser design is included in the report titled, *Harbor Island Desalination Plant – Effluent Diffuser Conceptual Design* (June 24, 2021), submitted by Lial Tischler, Ph.D., P.E. of Tischler/Kocurek Environmental Engineers.

Outfall 001 Discharge Characteristics

Outfall 001 will consist of a submerged multi-port diffuser, located approximately 69.8 meters (~229 feet) from the shoreline and oriented approximately parallel to the bank. According to the revised application, the diffuser barrel will be located on a steeply sloping side of an eddy-generated "hole" in the channel. However, the actual depth at which the barrel will be located will be determined in the final design based on construction requirements and the side slope of the channel. At the proposed permitted flowrate of 95.6 MGD, the diffuser will consist of 20 ports, each with a diameter of 0.18 meter (7 inches) and oriented 30 degrees upwards towards the water surface. The port height above the channel bottom is 7.9 meters (26 feet), and the depth of the water body where the ports discharge is approximately 90 feet.

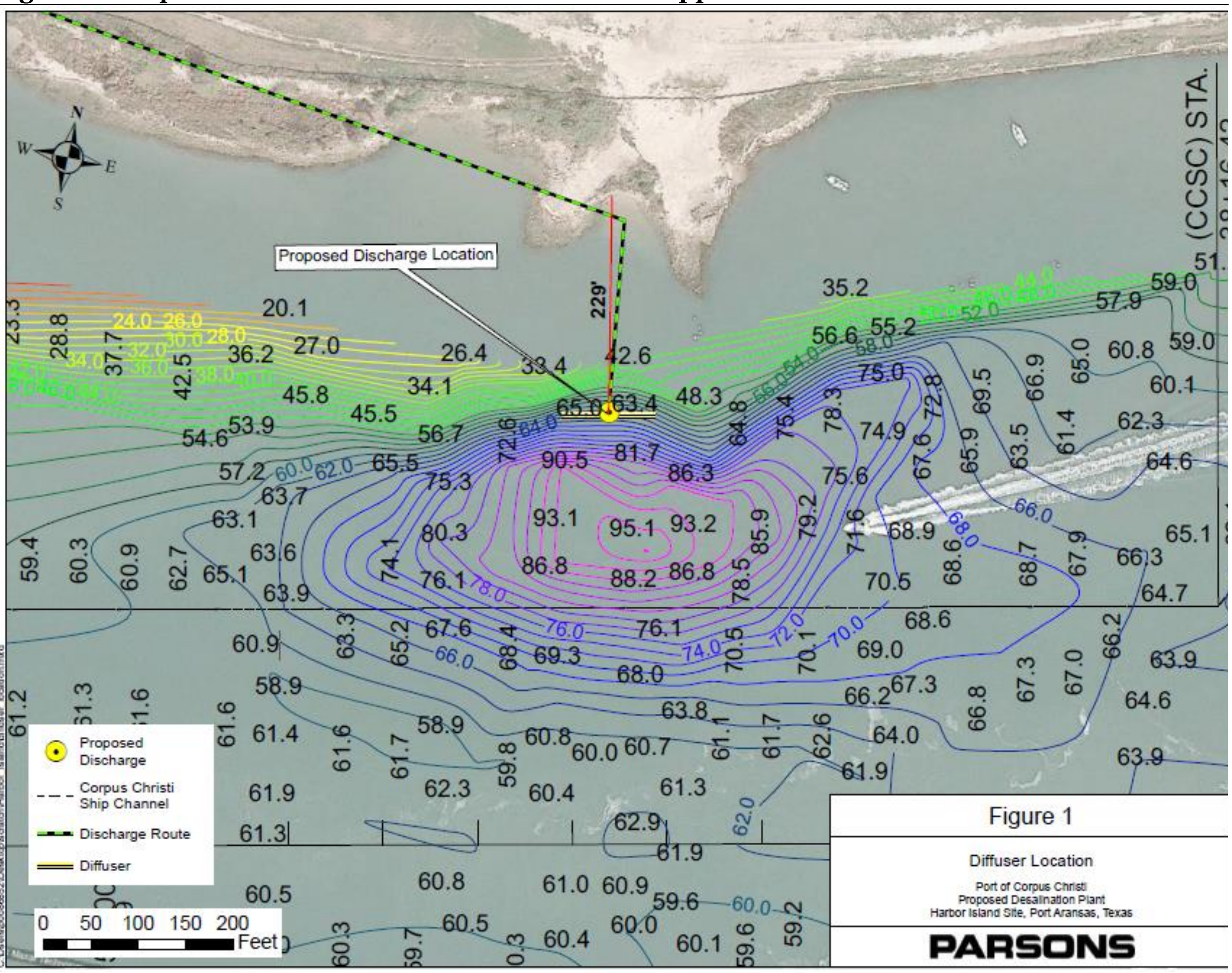
In summary, the revised diffuser design will have the following characteristics:

- number of ports = 20*
- length of diffuser barrel = 30 meters (98.4 feet)
- diffuser distance from shoreline = 69.8 meters (229 feet)
- water body depth at discharge (HD) = 27.4 meters (~90 feet)
- average water body depth (HA) = 18.3 meters (actual); 22 meters (in model)
- port centerline height above local channel bottom (H0) = 7.9 meters (26 feet)
- port diameter = 0.18 meter (7 inches)
- alignment angle between the diffuser line and ambient current **(GAMMA)** = 0˚ (parallel to the ambient current)
- port angle from horizontal **(THETA)** = 30˚ (ports point upward towards the water surface)
- port angle from vertical **(SIGMA)** = 270˚ (ports discharge perpendicular to ambient flow)
- relative orientation angle between the horizontal projection of the average port centerline direction and the diffuser axis **(BETA)** = 90˚ (ports are oriented normal to the diffuser line (unidirectional diffuser))

*The 20-port diffuser configuration corresponds to discharge at the proposed permitted flowrate of 95.6 MGD. The applicant's submittal explains that if the effluent flowrate decreases by more than 10%, the diffuser ports can be blocked, or smaller diameter ports can be used to maintain the same port exit velocity (~8.2 m/s). According to the submittal, when this port exit velocity is maintained, the diffuser can achieve the same effluent dilutions at lower effluent flowrates. While the specifics of the diffuser design at lower flowrates are not evaluated in this review, the permittee is required to maintain the diffuser such that the maximum percentage of effluent (or less) is still achieved, regardless of the discharge flowrate.

Discharge location:
In the original application, the proposed diffuser was planned to be located approximately 300 feet from the shoreline. However, the amended application indicates that the proposed diffuser will be approximately 229 feet from the shoreline and will be located on the north slope of an eddy-generated "hole" in the channel. At the revised diffuser location, the applicant's diffuser report indicates that the local depth of the water body is 27.4 meters (90 feet). Figure 1 is from the amended application, and where the diffuser is proposed, the bathymetry map indicates the depth of the water body is approximately 20 meters (65 feet). However, the applicant later clarified that because the diffuser is located on a steeply sloping side of the channel and because the ports discharge at an angle of 30 degrees to the horizontal and point across the channel toward the opposite bank, the resulting depth of the channel at which the effluent discharges into is approximately 90 feet.

Figure 1: Proposed Diffuser Location from Revised Application



Modeling Software:
An analysis of the discharge via Outfall 001 was performed using CORMIX 11.0GTD (Version 11.0.1.0) hydrodynamic mixing zone modeling software.

Ambient Conditions

Data Source:
Ambient density information was retained from previous reviews of this permit application from Surface Water Quality Monitoring (SWQM) Station 16492.

Data from SWQM Station 13407 was also used in this review to develop two of the stratification cases. This SWQM station is located in the Corpus Christi Bay. I incorporated data from this station since it has temperature and salinity measurements collected at deeper (~60 feet) depths than SWQM Station 16492.

Table 1: Ambient Densities Retained from the 2018 and 2020 Diffuser Reports (SWQM Station 16492)

Density Combination	**Summer**	**Winter**
ρ(T5, S5)	1018.75	1017.63
ρ(T5, S95)	1026.70	1025.40
ρ(T95, S5)	1017.76	1016.39
ρ(T95, S95)	1025.64	1024.03

The applicant collected additional water quality samples in the immediate discharge location. The temperature and salinity measurements collected by the applicant are similar to the data collected at SWQM Station 16492. A summary of the the water column averaged temperature and salinity values and calculated densities are shown in Table 2. The values listed below are based on the applicant's samples using a 100-ft cable. The applicant collected additional water quality samples using a shorter cable, but only the samples from the 100-ft cable are included in Table 2.

Table 2: Water Quality Data Collected by Applicant

Date and Time	**Water column averaged temperature (˚C)**	**Water column averaged salinity (ppt)**	**Water column average density (kg/m^3)**
6/9/2021 14:35	27.03	28.25	1017.68
6/9/2021 16:04	27.31	25.65	1015.65
6/10/2021 12:44	27.49	27.75	1017.16
6/10/2021 14:58	27.64	27.88	1017.21

Ambient velocity:
All initial CORMIX cases were modeled using an ambient velocity of 0.8 m/s, which is the 50th percentile current, as recorded by the University of Texas Marine Science Institute (UTMSI) current meter located in Port Aransas, and is consistent with the applicant's revised submittal. The applicant collected site-specific velocities near the proposed discharge location using an acoustic doppler current profiler (ADCP) and also provided velocity information from other existing current meters for comparison to the velocity data collected by the ADCP.

Based on evidence in the initial hearing, CORMIX model predictions showed that the original diffuser design could not meet the original critical dilutions at higher ambient velocities (i.e., >0.05 m/s). To address this issue, sensitivity runs were constructed from the most critical, initial model case (**W_40_c**) using varying ambient velocities ranging from 0.05 m/s to 2 m/s. With the applicant's revised diffuser design, changing the ambient velocity within this range did not produce more stringent effluent percentages than the initial model cases. Table 3 summarizes the additional cases that were run to assess the effects of changes in ambient velocity.

Table 3: Ambient Velocities used in Mixing Analysis

Case ID	Ambient Velocity (m/s)	Notes
All Initial Cases	0.8	50th percentile velocity from UTMSI current meter; model predictions determined by x-coordinate
W_40_c_05	0.05	model predictions determined by y-coordinate
W_40_c_06	0.06	
W_40_c_08	0.08	model predictions determined by y-coordinate (ZID); model predictions determined by x-coordinate (MZ, HH)
W_40_c_09	0.09	
W_40_c_1	0.1	model predictions determined by x-coordinate
W_40_c_2	0.2	
W_40_c_3	0.3	
W_40_c_4	0.4	
W_40_c_5	0.5	
W_40_c_6	0.6	
W_40_c_7	0.7	
W_40_c_8	1	
W_40_c_9	1.2	
W_40_c_10	1.5	
W_40_c_11	1.7	
W_40_c_12	2.0	

Width and depth:

Outfall 001 discharges directly into the Corpus Christi Ship Channel, which is approximately 366 meters (~1,200 feet) wide and is configured as a uniform and unbounded water body in the model. The average depth of the water body is approximately 18.3 meters (60 feet). However, an average depth of 22 meters (72.2 feet) was used instead to accommodate model input constraints. Note that the average depth input is important for far-field transport only and does not affect near-field model predictions. Because the boundaries of the ZID and aquatic life mixing zone occur within the near-field region, the depth at the discharge location is the more critical depth parameter.

According to the revised application, the diffuser will be located on the north slope of an eddy-generated "hole" or depression in the channel. The CORMIX model is unable to simulate detailed bathymetry such as a hole. Rather, the water body is described in the model having a rectangular cross-section with a flat bottom.

Manning's n coefficient:

To approximate the measure of the channel's bottom roughness characteristics, a coefficient of 0.02 was used for all model runs, which is consistent with the TCEQ CORMIX guidance document. Based on the *CORMIX User Manual*, a value of 0.02 is representative of a channel type described as smooth with no weeds.

<u>**Discharge Conditions**</u>

Flow:

Based on the revised application (specifically in Attachment 8: Process Design Basis and Narrative), the desalination facility may operate at a 40% recovery rate or at a 50% recovery rate. When the facility is operating at a 40% recovery rate, the proposed effluent flowrate is 95.6 MGD. When the facility is operating at a 50% recovery rate, the proposed effluent flowrate is 83.1 MGD. Model runs were constructed using the proposed effluent flowrate of 95.6 MGD (modeled with effluent densities representative of a 40% and a 50% RO recovery rate) and at an effluent flowrate of 83.1 MGD (modeled with effluent densities representative of a 50% RO recovery rate) for comparison.

Effluent density:
The revised application indicates that the proposed seawater intake will be located in the Gulf of Mexico. The characteristics of the effluent quality vary based on the plant achieving a 40% RO recovery rate versus a 50% RO recovery rate. Tables 4 and 5 summarize the effluent characteristics.

Table 4: Effluent Densities based on 40% RO Recovery

Season	Density Condition	Salinity (ppt)	Temperature (°C)	Density (kg/m³)
Summer	ρ(T5, S5)	46.8	26.55	1031.74
Summer	ρ(T5, S95)	59.7	26.55	1041.42
Summer	ρ(T95, S5)	46.8	30.71	1030.22
Summer	ρ(T95, S95)	59.7	30.71	1039.79
Winter	ρ(T5, S5)	35.9	11.11	1027.41
Winter	ρ(T5, S95)	51.6	11.11	1039.73
Winter	ρ(T95, S5)	35.9	18.33	1025.87
Winter	ρ(T95, S95)	51.6	18.33	1037.96

Table 5: Effluent Densities based on 50% RO Recovery

Season	Density Condition	Salinity (ppt)	Temperature (°C)	Density (kg/m³)
Summer	ρ(T5, S5)	53.9	26.55	1037.01
Summer	ρ(T5, S95)	68.7	26.55	1048.15
Summer	ρ(T95, S5)	53.9	30.71	1035.43
Summer	ρ(T95, S95)	68.7	30.71	1046.44
Winter	ρ(T5, S5)	41.2	11.11	1031.62
Winter	ρ(T5, S95)	59.4	11.11	1045.79
Winter	ρ(T95, S5)	41.2	18.33	1030.00
Winter	ρ(T95, S95)	59.4	18.33	1043.91

From the ambient and effluent density combinations, 24 CORMIX model cases were initially constructed. The initial CORMIX model cases based on a 40% RO recovery rate are summarized in Table 6.

Table 6: CORMIX Cases Evaluated at 40% RO Recovery Rate

Case	Ambient	Effluent		Case Description
	Density (kg/m³)	Density (kg/m³)	Flow (MGD)	
S_40_a	1018.75	1031.74	95.6	T_5S_5 – summer – proposed effluent flowrate at 40% recovery
S_40_b	1026.70	1041.42	95.6	T_5S_{95} – summer – proposed effluent flowrate at 40% recovery
S_40_c	1017.76	1030.22	95.6	$T_{95}S_5$ – summer – proposed effluent flowrate at 40% recovery

Table 6: CORMIX Cases Evaluated at 40% RO Recovery Rate

Case	Ambient	Effluent		Case Description
	Density (kg/m^3)	Density (kg/m^3)	Flow (MGD)	
S_40_d	1025.64	1039.79	95.6	$T_{95}S_{95}$ – summer – proposed effluent flowrate at 40% recovery
W_40_a	1017.63	1027.41	95.6	T_5S_5 – winter – proposed effluent flowrate at 40% recovery
W_40_b	1025.40	1039.73	95.6	T_5S_{95} – winter – proposed effluent flowrate at 40% recovery
W_40_c	1016.39	1025.87	95.6	$T_{95}S_5$ – winter – proposed effluent flowrate at 40% recovery
W_40_d	1024.03	1037.96	95.6	$T_{95}S_{95}$ – winter – proposed effluent flowrate at 40% recovery

The initial CORMIX model cases based on a 50% RO recovery rate are summarized in Table 7.

Table 7: CORMIX Cases Evaluated at 50% RO Recovery Rate

Case	Ambient	Effluent		Case Description
	Density (kg/m^3)	Density (kg/m^3)	Flow (MGD)	
S_50_a	1018.75	1037.01	83.1	T_5S_5 – summer – proposed effluent flowrate at 50% recovery
S_50_b	1026.70	1048.15	83.1	T_5S_{95} – summer – proposed effluent flowrate at 50% recovery
S_50_c	1017.76	1035.43	83.1	$T_{95}S_5$ – summer – proposed effluent flowrate at 50% recovery
S_50_d	1025.64	1046.44	83.1	$T_{95}S_{95}$ – summer – proposed effluent flowrate at 50% recovery
W_50_a	1017.63	1031.62	83.1	T_5S_5 – winter – proposed effluent flowrate at 50% recovery
W_50_b	1025.40	1045.79	83.1	T_5S_{95} – winter – proposed effluent flowrate at 50% recovery
W_50_c	1016.39	1030.00	83.1	$T_{95}S_5$ – winter – proposed effluent flowrate at 50% recovery
W_50_d	1024.03	1043.91	83.1	$T_{95}S_{95}$ – winter – proposed effluent flowrate at 50% recovery
S_50_a_95	1018.75	1037.01	95.6	T_5S_5 – summer – proposed permitted effluent flowrate
S_50_b_95	1026.70	1048.15	95.6	T_5S_{95} – summer – proposed permitted effluent flowrate
S_50_c_95	1017.76	1035.43	95.6	$T_{95}S_5$ – summer – proposed permitted effluent flowrate
S_50_d_95	1025.64	1046.44	95.6	$T_{95}S_{95}$ – summer – proposed permitted effluent flowrate
W_50_a_95	1017.63	1031.62	95.6	T_5S_5 – winter – proposed permitted effluent flowrate

Table 7: CORMIX Cases Evaluated at 50% RO Recovery Rate

Case	Ambient	Effluent		Case Description
	Density (kg/m^3)	Density (kg/m^3)	Flow (MGD)	
W_50_b_95	1025.40	1045.79	95.6	T_5S_{95} – winter – proposed permitted effluent flowrate
W_50_c_95	1016.39	1030.00	95.6	$T_{95}S_5$ – winter – proposed permitted effluent flowrate
W_50_d_95	1024.03	1043.91	95.6	$T_{95}S_{95}$ – winter – proposed permitted effluent flowrate

Stratification Cases:

Based on the results of the initial CORMIX cases, it was evident that neither changes in the ambient density nor seasonal variation had a significant impact on model results. From the initial 24 cases modeled, the results were nearly identical. However, case **W_40_c** resulted in slightly more stringent predictions at the human health mixing zone boundary, so an additional stratification case was developed from this case. Additionally, a summer stratification case was also developed for initial case **S_40_c**. Since the applicant also collected water quality samples near the proposed discharge location, a third stratification case was run using this data on summer case **S_40_c** using the 4 sets of water quality samples that were collected on 6/9/2021 and 6/10/2021 using a 100-foot cable.

For all stratification cases, CORMIX noted that the ambient density stratification was unimportant and that the discharge would behave as if the ambient were unstratified. None of these stratification cases resulted in more stringent model predictions. Table 7 summarizes the surface and bottom ambient densities used in each stratification case.

Table 7: CORMIX Stratification Cases Evaluated

Case	Ambient	Effluent		Case Description
	Density (kg/m^3)	Density (kg/m^3)	Flow (MGD)	
W_40_c_strat	1016.27 (surface) 1016.51 (bottom)	1025.87	95.6	Developed from Case W_40_c
S_40_c_strat	1016.92 (surface) 1017.57 (bottom)	1030.22	95.6	Developed from Case S_40_c using applicant's WQ samples collected on 6/10/2021 14:58
S_40_c_strat_2	1017.52 (surface) 1018.00 (bottom)	1030.22	95.6	Developed from Case S_40_c

Results and Discussion

Since the discharge is through a multi-port diffuser, the regulatory mixing zones are rectangular in shape but have equivalent areas to the standard radial mixing zones for wide (≥400 feet) tidal rivers and bays. Because all the ports point in the same direction towards the opposite shoreline, the mixing zones are configured with one edge (i.e., Side A) along the barrel of the diffuser and parallel to the shoreline.

Table 8: Regulatory Mixing Zone (RMZ) Dimensions

	Side A (x, downstream)	Side B (y, across channel)	Area
ZID	56 m (184 ft)	13 m (43 ft)	730 m^2 (7,854 ft^2)
MZ	168.5 m (553 ft)	69.3 m (227 ft)	11,675 m^2 (125,664 ft^2)
HH	321 m (1,053 ft)	145.5 m (477 ft)	46,698 m^2 (502,655 ft^2)

Note that on page 5 of Dr. Tischler's diffuser report, the 'x' and 'y' dimensions for the human health mixing zone are switched (i.e., x = 145.5 meters; y = 321 meters). However, in Table 4 of his report and in his CORMIX prediction files, the dimensions for the human health mixing zone are given as: x = 321 meters and y = 145.5 meters. The applicant later clarified that the correct dimensions for the human health mixing zone are x = 321 meters and y = 145.5 meters. Thus, the human health mixing zone dimensions on page 5 are a typographical error.

Because the regulatory mixing zones are defined in the draft permit as being centered on the diffuser barrel and since the receiving water body is tidal, the plume can move upstream (towards Corpus Christi Bay) and downstream (towards the Gulf of Mexico). CORMIX defines the origin of the coordinate system at the mid-point of the diffuser axis. Therefore, I evaluated the location at which the plume centerline intersects the regulatory mixing zones at one-half of the downstream distance in the x-direction (i.e., ZID verified at x = 28 m; MZ verified at x = 84.3 m; HH verified at x = 160.5 m). This is a conservative approach to evaluate the effluent percentage at each regulatory mixing zone boundary. Because the results of this diffuser review are used in the Antidegradation review by the Standards Implementation Team to determine salinity levels at the mixing zone boundaries, I evaluated the mixing zones in this way to assign the final effluent percentages. Figure 3 illustrates the configuration of the regulatory mixing zones assigned to Outfall 001.

Figure 3: Regulatory mixing zones centered on the diffuser barrel. Dimensions extend upstream (towards Corpus Christi Bay) and downstream (towards the Gulf of Mexico).

For comparison, Dr. Tischler evaluated the model predictions at the full downstream extent of each regulatory mixing zone (i.e., ZID verified at x = 56.1 m; MZ verified at x = 168.6 m; HH verified at x = 321 m). However, for the reasons mentioned previously, I evaluated the model predictions at the mixing zone boundaries as shown in Figure 3.

Table 8 summarizes the predicted effluent concentrations for each model case at the edge of each regulatory mixing zone.

Table 8: CORMIX Model Results (% effluent)

Case	ZID %	MZ %	HH %
S_40_a	14.6	8.9	5.2
S_40_b	14.6	8.9	5.2
S_40_c	14.6	8.9	5.3
S_40_d	14.6	8.9	5.2
W_40_a	14.6	8.9	5.4
W_40_b	14.6	8.9	5.2
W_40_c	14.6	8.9	5.4
W_40_d	14.6	8.9	5.2
S_50_a	14.6	8.9	5.0
S_50_b	14.6	8.9	5.0
S_50_c	14.6	8.9	5.0
S_50_d	14.6	8.9	5.0

W_50_a	14.6	8.9	5.1
W_50_b	14.6	8.9	5.0
W_50_c	14.6	8.9	5.1
W_50_d	14.6	8.9	5.0
S_50_a_95	14.6	8.9	5.1
S_50_b_95	14.6	8.9	5.1
S_50_c_95	14.6	8.9	5.1
S_50_d_95	14.6	8.9	5.1
W_50_a_95	14.6	8.9	5.1
W_50_b_95	14.6	8.9	5.1
W_50_c_95	14.6	8.9	5.2
W_50_d_95	14.6	8.9	5.1
W_40_c_strat	14.6	8.9	5.4
S_40_c_strat	14.6	8.9	5.2
S_40_c_strat_2	14.6	8.9	5.3
W_40_c_05	4.6	3.3	2.6
W_40_c_06	4.8	3.5	2.8
W_40_c_08	12.8	6.6	4.2
W_40_c_09	12	7	4.4
W_40_c_1	12.3	7.4	4.6
W_40_c_2	14.6	8.9	5.4
W_40_c_3	14.6	8.9	5.4
W_40_c_4	14.6	8.9	5.4
W_40_c_5	14.6	8.9	5.4
W_40_c_6	14.6	8.9	5.4
W_40_c_7	14.6	8.9	5.4
W_40_c_8	14.6	8.9	5.3
W_40_c_9	14.6	8.9	5.3
W_40_c_10	14.6	8.9	5.3
W_40_c_11	14.6	8.9	5.3
W_40_c_12	14.6	8.9	5.3

Discussion:
The model results for all cases predict the plume to be negatively buoyant since the effluent has a greater density than the receiving water body in all cases. Variations in the ambient densities did not have a significant impact on model results nor did scenarios in which a stratified ambient density were modeled. Changes in ambient velocity also did not produce more stringent results than the initial model cases using the 50th percentile velocity (0.8 m/s).

The applicant's submittal notes that the proposed diffuser is designed to have a discharge velocity of approximately 8.2 m/s. The CORMIX model notes that a discharge velocity less than 2.5 m/s may be recommended to avoid possible adverse conditions for sensitive fish populations. However, this issue is outside the scope of the critical conditions/diffuser review.

Recommended effluent percentages:
Based on the CORMIX analysis, the following percentages of effluent are recommended at the edges of each regulatory mixing zone:

ZID = 14.6%
MZ = 8.9%
HH = 5.4%